Original Article

Aerobiology as a tool to help in episodes of occupational allergy in work places

P. Cariñanos, P. Alcázar, C. Galán, R. Navarro, E. Domínguez

Plant Biology Department. University of Córdoba. Campus Universitario de Rabanales. Colonia San José 4. Ctra. Madrid, Km 396. E-14071 Córdoba, Spain.

Abstract. Over 80% of weekday time is spent indoors and the air quality of this environment may affect the incidence of symptoms in allergy sufferers. However, indoor/outdoor measurements have been jointly considered only in a few studies. The objective of this paper is to analyse indoor/outdoor biological and non-biological particle content togeher with other factors affecting the severity of symptoms during working periods in an Aerobiology Lab during the most troublesome period of the year for allergy sufferers. For this purpose, indoor/outdoor air samples were taken using standard portable particle traps at the National Coordinating Centre of the Spanish Aerobiology Network, University of Cordoba. The analysis differentiated between biological and non-biological material, and the allergy symptoms suffered by workers were quantified and correlated accordingly. An inventory of the incoming and outgoing sources of emissions was done in order to identify agravating co-factors. The results showed that since there was very little air movement between indoors and outdoors, there was a significant difference in the amount of biological material present in the two areas. The presence of some indoor source of emissions, such as the Plant Collections property of the Department, the Air Conditioned System and the volatile compounds of the copying machine was responsible of high particle content. External factors such as weather conditions or human activities contributed exacerbating symptoms. As Conclusion, the knowledge of airborne biological particle content could be a useful tool in minimising allergy symptoms when environmental conditions render them inevitable.

Keywords: Occupational Allergy, Aerobiology, indoor/outdoor particle content, air quality, pollen allergy, indoor environment, allergenic activity, pollinosis symptoms, asthma.

Introduction

Most citizens in an urban environment spend over 80% of weekdays inside closed buildings. Attendance at school (6 hours/day), full-time jobs (7 hours/day), time at home (6-8hours/day), together with more recent indoor leisure activities such as shopping-centres, cinemas, restaurants and children's play centres, result in much less time spent in the open air. Moreover, fresh air has traditionally been considered more polluted and of worse quality than the air we breathe indoors [1-6]. However, many studies have addressed the effects of pollution on human health using stationary outdoor particle traps. Only on a few occasions have indoor/outdoor measurements been considered jointly [7-9].

The team at the National Coordinating Centre of the Spanish Aerobiology Network (REA) has been monitoring airborne biological content in the city of Cordoba for the last twenty years. On occasions, the data generated has been "useful first-hand information" for those members of the team who are themselves hay-fever patients. Latterly, however, poor air quality has adversely affected not only known allergy sufferers, who experience more frequent crises and more aggressive

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symptoms, but also people who are not generally allergy sufferers, but who at times complain of sporadic discomfort. There has been a widely-recorded increase in allergy incidence over the last few decades, due to a number of factors, both environmental (e.g. pollution or smoking habits) and genetic [10, 11]. However, most adverse reactions take place during working time and in the work place. What is happening? Are we developing an occupational allergy? By definition, occupational allergy is any kind of clinical or physio-pathological event due to hypersensitivity prompted by an agent in the work place. Since particles of biological origin such as pollen grains and fungal spores are the raw material used in our daily work, and admitting the presence of some “hot spots” of fungal spore production (plant collections, heating and air conditioning systems, surrounding natural vegetation), it could be argued that our working environment is detrimental to our health, even though – paradoxically – we are helping others to minimize their allergic symptoms through our Pollen Allergy Prevention Service.

This paper presents the results obtained from the analysis of the indoor/outdoor biological (pollen grains and fungal spores) and non-biological particle content in an Aerobiology lab over a year characterised by high incidence of pollen load in the outdoor atmosphere, and therefore particularly troubling for all allergy sufferers. All external and internal parameters that might be involved in symptom worsening or the appearance of symptoms in non-atopic individuals were also considered.

Materials and Methods

The study was carried out in the Plant Biology building at the University of Cordoba, city of Cordoba, in the south-west of the Iberian Peninsula (37º50´N, 4º45´W; 123m a.s.l.). The Department occupies a block of 4 old houses on two floors in the eastern section of the Campus. The whole Campus, and the Department in particular, is located in the countryside, surrounded by wild species representative of Mediterranean vegetation: ornamentals (plane trees, mulberries, Pride of India, Bean tree, Cypress, privets, Eucalyptus etc…) and rainfed crops: olive, sunflower and cereals.

Meteorological parameters over the study period were obtained from the Campus weather station, run by the Central Research Support Service of the University of Córdoba. The data considered were those relating to daily maximum and minimum temperatures, relative humidity and total daily precipitation. Information regarding mowing activities in the area surrounding the building during the study period was also considered, due to the large number of micro-particles (diameter less than 2.5 mm) generated, mostly of plant origin.

Indoor/outdoor air samples were taken using three volumetric suction samplers, two of them portable (Lanzoni VPPS 1000, Lanzoni s.r.l. Bologna, Italy) placed at a height of 1.5m a.g.l. inside/outside the building, separated by a closed window on the ground floor. The third one was stationary (Lanzoni VPPS 2000, Lanzoni s.r.l. Bologna, Italy), placed at a height of 15m a.g.l., in the Main Hall on the Campus, without any obstacle impeding the free flow of air. This is one of the samplers conforming the local aerobiology infraestructure covering the urban area of Córdoba. The samplers worked 24h/day on working days from May 16th to June 1st 2002. The methodology used to analyse the samples was that proposed by the Spanish Aerobiology Network [12]. The main allergenic pollen types flowering during this period of the year (*Olea, Poaceae, Quercus, Plantago* and *Urticaceae*), as well as the most commonly-reported allergenic fungal spores (*Cladosporium*, *Alternaria*, *Aspergillus*), were treated separately from the total amount of biological particles present in the samples.

The Staff of the Department consists of 30 full-time employees, 8 of whom volunteered for this study. The volunteers were asked to provide data on matters of interest such as: smoker/non smoker; diagnoses of rhinitis, conjunctivitis and/or asthma, as well as age and other general data. All were provided with a form to note down daily symptoms and medication taken. Most volunteers work on the ground floor, all the rooms having windows and being close to the only entrance door to the building. Both windows and doors are normally kept closed to avoid loss in air-conditioning power, to prevent insects from getting in and to minimize surrounding noise. In accordance with the legislation currently in force, smoking is prohibited throughout the building.

All allergy sufferers taking part had positive diagnoses to pollen grains, so, as well as obtaining correlation statistics between the pollen concentrations from the three sites, we also looked for correlation between the three pollen concentrations and the symptoms manifested by the volunteers.

Results

Table 1 shows the main characteristics of the volunteers participating in this study. All of them are regular workers at the Plant Biology Department of the University of Córdoba. The first five, meaning the 16.6% of the totality of the Staff, have a positive diagnosis to several different pollen types, mainly *Olea*, grasses, *Platanus* and *Chenopodiaceae*. The last three were included as controls to observe the appearance of symptoms in non-atopic or non-diagnosed patients. Among the atopics, patients 3 and 4 also present positive diagnoses to mites (*Dermatophagoides*) and suffer from

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Table 1. Patients' characteristics and diary of symptoms during the period of study.

Patient	Atopic (allergy and/or Asthma)	Age/Sex	Area of Residence	Medical treatment	Diary: May-16th	Diary: May-17th	Diary: May-20th	Diary: May-21st	Diary: May-22nd	Diary: May-23rd	Diary: May-24th	Diary: May 27th	Diary: May-28th
1	Pollen allergy	35/ Female (non smoker)	City Centre	Antihistamine (1dose/day)	Eye and throat itching	* Rhinoconjunc. Eye-itching	* Rhinoconjunc Eye-itching.	* Rhinoconjunc	* Rhinoconjunc Breathing difficulties	* Acute crisis Breathing difficulties	* Acute crisis Breathing difficulties	* Slight recovery Coughing	Rhinoconjunc
2	Pollen allergy	26/Female (occasionally smoker)	On Campus	Antihistam (1dose/day) Collyrium Bronchodilators	* Slight symptoms	* Rhinoconjunc. Eye-itching Coughing	* Rhinoconjunc. Eye-itching Coughing	* Rhinoconjunc. Eye-itching Coughing	Slight symptoms Worsening at night	Rhinoconjunc. Eye-itching Coughing	* Rhinoconjunc. Eye-itching Coughing	* Worsening during weekend asthma attack	* Slight recovery Coughing
3	Pollen, mites, spores allergic/asthma	27/Male (non smoker)	Northern suburb	Antihistam. Bronchodilators (all year round)	* Rhinoconjunc. Eye-itching	* Rhinoconjunc. Eye-itching	* Rhinoconjunc. Eye-itching	* Rhinoconjunc. Eye-itching	* Rhinoconjunc. Eye-itching	* Absent from Lab	* Rhinoconjunc. Eye-itching	* Rhinoconjunc. Eye-itching	* Rhinoconjunc. Eye-itching
4	Mites, pollen allergic/bronchial asthma	36/Female (non smoker)	City Centre	(no smoker). (2doses/day) Bronchodilators	Acute asthma attack	* Breathing difficulties Coughing Eye-itching	* eye nose itching sneeze	* Slight recovery Symptoms less severe	* asthma attack at night	* Rhinoconjunc.	* Rhinoconjunc.	Asthma attack	Eye-itching coughing
5	Pollen allergic	42/Female (non smoker)	Northern suburb	Antihistam. (when symptoms)	Eye/throat itching Complications with a cold	Rhinoconjunc. Bronchitis worsening	Rhinoconjunc. Bronchitis recovering	Absent from lab	Rhinoconjunc.	Rhinoconjunc.	No symptoms	No symptoms	No symptoms
6	No	32/Female (non smoker)	Northern suburb	When symptoms	Discomfort Eye/nose/throat itching	Discomfort	No symptoms	No symptoms	Discomfort Eye/nose/throat itching	No symptoms	No symptoms	No symptoms	No symptoms
7	No	25/Male (non smoker)	Southern District	No	No symptoms	No symptoms	No symptoms	No symptoms	No symptoms	No symptoms	No symptoms	No symptoms	No symptoms
8	No diagnoses (suspicion)	38/Female (non smoker)	Western district	Antihistam.	Eye/throat itching	* No symptoms	* Eye/throat itching	* No symptoms	* Eye/throat itching	* No symptoms	* No symptoms	* No symptoms	* No symptoms

* indicates days in which the patients took medication.

Table 2. Meteorological parameters (Maximum and minimum temperature, Relative Humidity and precipitation) and indication of reaping during the period of study.

Date	**May-16th**	**May-17th**	**May-20th**	**May-21st**	**May-22nd**	**May-23rd**	**May-24th**	**May-27th**	**May-28th**	**May-29th**	**June-1st**
Meteorological Parameters	Max. Tª: 36.8 Min. Tª: 14.0 R.H. 40.6% Prec. 0 mm	Max. Tª: 26.6 Min. Tª: 15.4 R.H. 55.3% Prec. 0 mm	Max. Tª: 32.0 Min. Tª: 11.4 R.H. 38% Prec. 0 mm	Max. Tª: 30 Min. Tª: 13.2 R.H. 47% Prec. 0 mm	Max. Tª: 25.4 Min. Tª: 14.6 R.H 56% Prec. 2.6 mm	Max. Tª: 25.6 Min. Tª: 9.6 R.H. 43.6% Prec. 0 mm	Max. Tª: 30.6 Min. Tª: 9.6 R.H. 49.3% Prec. 0 mm	Max. Tª: 28.4 Min. Tª: 10.4 R.H. 39.3% Prec. 0 mm	Max. Tª: 31.0 Min. Tª: 8.6 R.H. 38.3% Prec. 0 mm	Max. Tª: 33.4 Min. Tª: 11.3 R.H. 37.6% Prec. 0 mm	Max. Tª: 29.4 Min. Tª: 10.4 R.H. 52% Prec. 0 mm
Reaping (distance)	Yes (round the building)	Yes (round the building)	Yes (300 m. from the building)	No	No	No	No	Yes (700 m. From the building)	No	No	No

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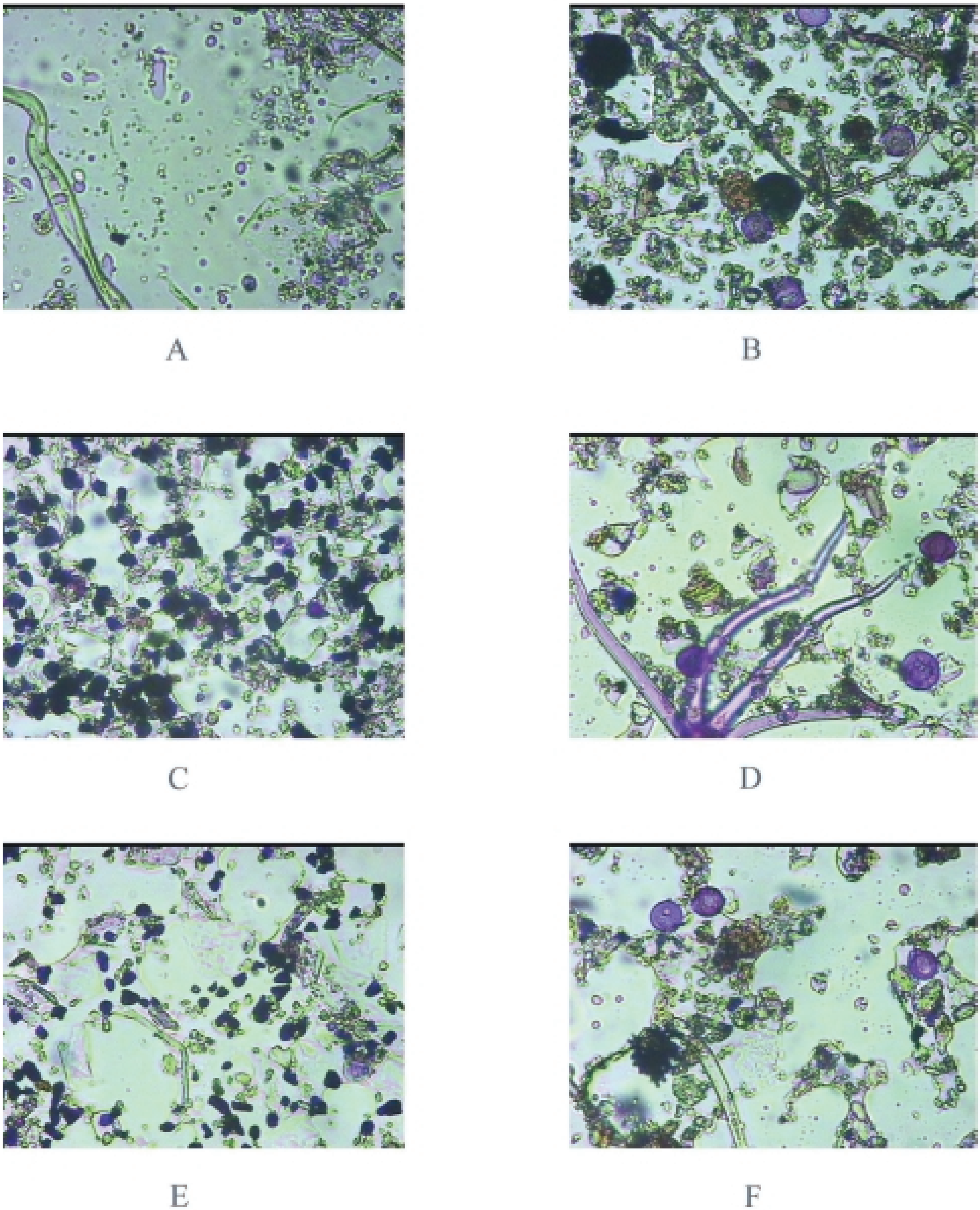

Figure 1. Particles collected with the samplers placed in and out the building at a height of 1,5 m a.g..1, A, C, D correspond to indoor samples. B, D, F correspond to outdoor samples. A-B were collected on May, the 20th; C-D were collected on May, the 22nd; E-F were collected on May, the 27th.

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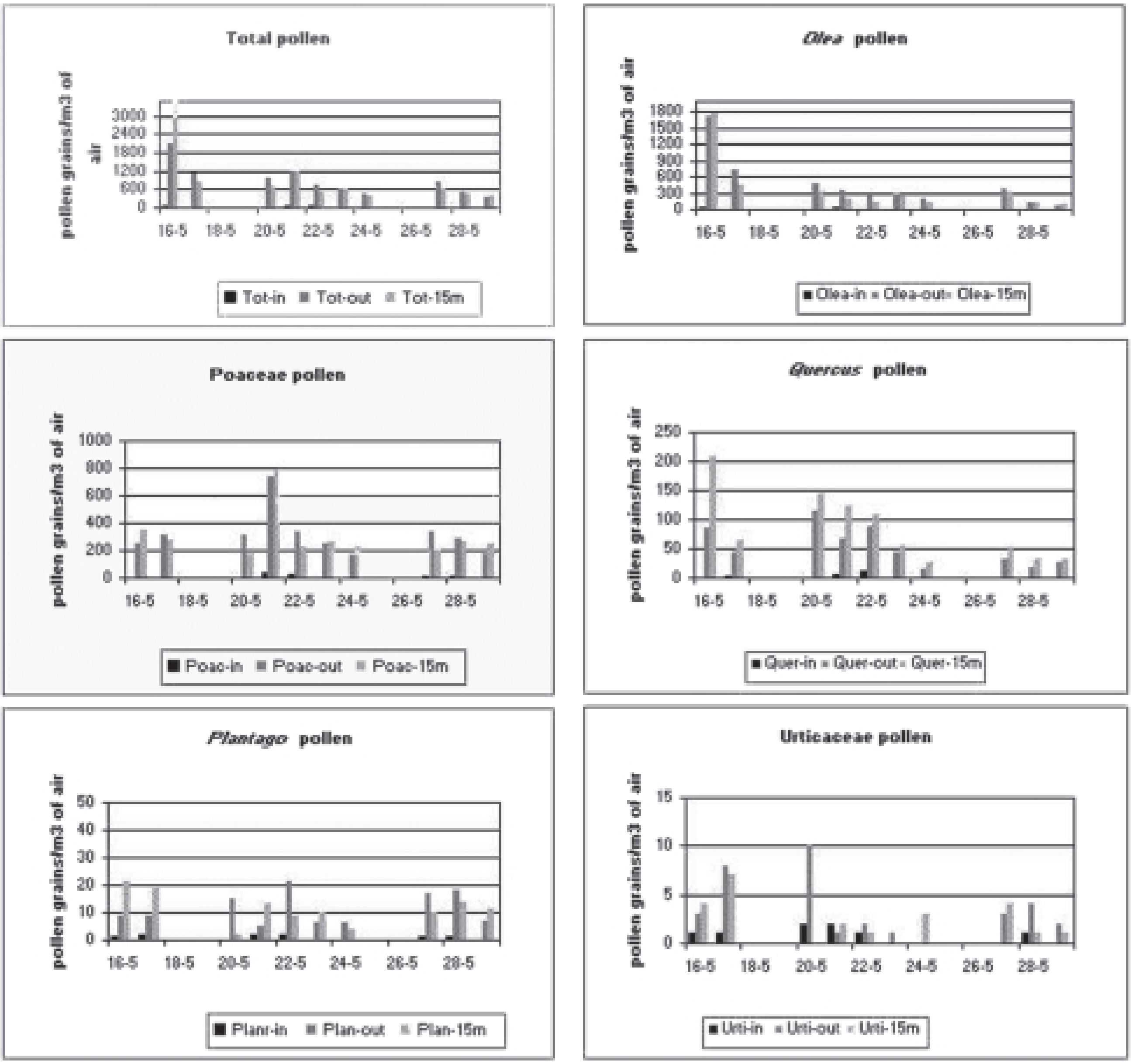

Figure 2a. Pollen captures with the three samplers: indoor, outdoor at 1,5 m and outdoor at 15 m.

perennial bronchial asthma. While patient 3 takes medication all year round, patient 4 only takes medication during certain periods of the year, mainly coinciding with the flowering of plane trees (mid-March, beginning of April), and in May when *Olea* and grasses show a simultaneous peak. This patient usually suffers from one acute asthma attack or occasionally two during the year.

Table 2 shows the meteorological conditions during the study period that may be considered relevant. The temperatures showed strong variations from one day to another (i.e. the maximum temperature on May 17th was 10.2ºC lower than the maximum temperature recorded the day before, when it was 36.8ºC), and peaks and troughs were recorded throughout the following days. Relative environmental humidity also varied during the same days, from a minimum of 37% on May 29th, to a maximum of 56% on May 22nd. This was also the only day in the whole period in which any precipitation was recorded (2.6mm). Table 2 also records the mowing activities carried out close to the building during the same period because of its possible implication in symptom worsening. During the first two days of sampling, mowing was carried out among the grass and weeds close to the building. Details of the deposit of remains and the amount of particles collected indoors and outdoors can be observed in Figure 1. Apart from vegetal remains, particles emanating from the

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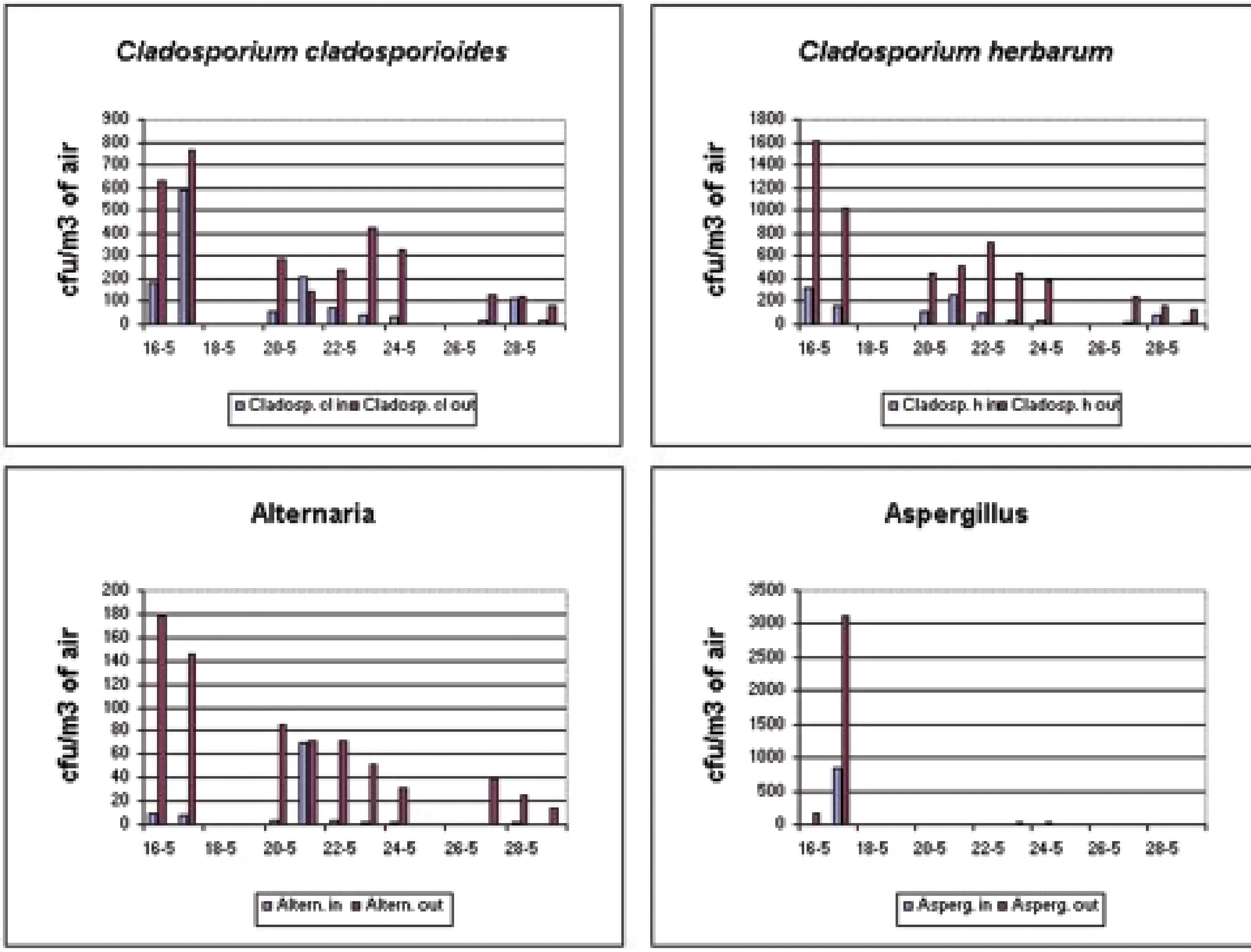

Figure 2b. Colony forming units (cgu) captures with the samplers placed indoor and outdoor at 1,5 m a.g.l.

exhaust of diesel engines, dust and soot from other sources, as well as material from biological sources, normally occur in the particle spectrum. Pictures A, C, E correspond to indoor samples collected during the 20th, 22nd and 27th of May respectively, while pictures B, D, F are the corresponding outdoor samples on the same dates. Biological material was always found in higher concentrations outside than inside, although plant residues were also present in the indoor samples (clearly in A). Pictures C and E are worth mentioning for the appearance of a kind of soot, regular-sized, not corresponding with material outside (pairs A-B, C-D, E-F were taken at the same time of day). The analysis of the material reveals the photocopying toner as the probable source, due to the sampler being in the copying room.

Figure 2a shows pollen captures with the samplers placed indoors or outdoors at a height of 1.5m and the third at a height of 15m a.g.l. In all cases, pollen counts indoors were the lowest. However, the highest values were sometimes recorded with the sampler outdoors at human height (*Olea* and grasses), and sometimes with the sampler at 15m a.g.l. (*Quercus* and *Plantago*). There is therefore no correlation between grass or tree pollen types and height of capture. Nettle pollen presented a very irregular distribution, with high values occurring at different times in different samplers. Apart from these 5 main pollen types, a total of 19 different types were collected during the time of the tests. Only 5 or 6 appeared regularly in the samples inside, the five main ones and *Rumex*. The rest were detected with higher frequency in the sampler placed at 1.5m than in the 15m sampler. Among the types worth mentioning there are: *Compositae* species, *Chenopodiaceae* species, *Echium*, *Cyperaceae*, *Cannabis*, *Castanea*, *Pinus*, *Brassicaceae* and *Cupressaceae*.

Figure 2b shows spore concentrations in colony forming units (cfu) collected inside and out at 1.5m height. Measurements at 15 m were not considered due to the strong influence of transitory microenvironmental conditions on the local presence of spores. Results corroborate the two types of *Cladosporium*, *Cl. cladosporioides* and *Cl. herbarum*, and *Alternaria sp.*

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		R	p
Totals	In-Out1.5	0.626	0.053
	In-Out15	0.541	0.106
	Out1.5-Out15	0.988**	0.000
Olea	In-Out1.5	0.438	0.206
	In-Out15	0.316	0.374
	Out1.5-Out15	0.939**	0.000
Poaceae	In-Out1.5	0.607	0.063
	In-Out15	0.085	0.815
	Out1.5-Out15	-0.036	0.920
Quercus	In-Out1.5	-0.013	0.972
	In-Out15	-0.117	0.747
	Out1.5-Out15	0.933**	0.000
Plantago	In-Out1.5	0.271	0.448
	In-Out15	0.480	0.160
	Out1.5-Out15	-0.070	0.847
Urticaceae	In-Out1.5	0.452	0.190
	In-Out15	-0.086	0.813
	Out1.5-Out15	0.084	0.817
Pinus	In-Out1.5	0.703*	0.023
	In-Out15	0.667*	0.035
	Out1.5-Out15	0.925**	0.000

Table 3. Spearman's correlation between the pollen concentrations detected with the three samplers: the one placed indoor (In), the one placed outdoor at 1.5 a.g.l (Out 1.5) and the third one placed also outdoor at a height of 15 m a.g.l. (Out 15).

as the most frequent types in the area. *Aspergillus* occurred only sporadically, but in significant quantities. As with pollen, spore concentrations were always higher outside than inside. All types followed similar patterns of distribution, i.e. high values during the early days and then a peak between the 22nd and 23rd of May.

Spearman´s correlation between the pollen concentrations collected with the different samplers (Table 3) shows that in most cases there is a significant relationship between the data from the two outdoor samplers, that is, between the one placed outside the building at a height of 1.5m and the one placed at a height of 15m a.g.l. The data obtained inside never correlate with either of them. When investigating the relationship between pollen concentrations and symptoms suffered (according to an established scale: 0: absence of symptoms; 1: mild symptoms; 2: moderate symptoms; 3: severe symptoms), no significant correlation was obtained (table not included).

Discussion

The aerobiological measurements carried out in different environments reveal differences depending on both the indoor or outdoor situation and on the height of placement. Some studies have shown that the indoor particle content is significantly reduced with respect to the one outdoors [13]. However, if PM2.5 and PM10 are considered, the variations are lower due to its particles being small enough to enter [7, 8]. On some occasions, the indoor biological content can be even higher than outdoors due to the indoor presence of sources of emissions [9]. In our case, we have corroborated that the indoor pollen captures are always the lowest, hardly reaching 5% of the outdoor captures. There is a clearer relationship between the concentrations detected with the two outdoor samplers. In general, the total quantities are slightly higher in the sampler placed at 1.5m above ground level, coinciding with some results that show differences of more than 30% in the pollen captures from samplers placed at different heights [14,15].

Smaller differences between in and out captures have been found in the case of spores, with a similar presence both in and out on some days and for some types. The explanation for this fact could be found in the size of some of the fungal spores, smaller than 5 micrometers in the case of *Aspergillus* and *Cl. cladosporioides*, making it possible for them to enter through the smallest gaps, even through badly fitting old windows. This would explain the presence of *Aspergillus* inside on the same day that an *Aspergillus* cloud was detected outside. However, there may be other causes intervening in the high presence of larger fungal spores inside. During the season in which the study took place, the air conditioned system is usually on. Under conditions of adequate environmental humidity, temperature and shade, fungal colonies proliferate very quickly, and the air conditioning pipes constitute a real culture medium. The Department's plant collection, consisting of more than 30,000 leaves, was also routinely removed at that time due to the arrival of new material. Although not many studies have been done on the minimum number of spores necessary to trigger off allergic symptoms in sensitive people, the three species found in the air samples have been reported as major causatives of respiratory pathologies associated with moulds [16, 17].

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No statistical correlation between the day-to-day pollen counts and the demonstration of symptoms in affected people has been found. This fact would support the certain phase lag existing between exposure to allergens and occurrence of symptoms [18-21], and also the establishment of cross-reactions between some pollen types simultaneously at their maximum [22]. This year, unusually, a coincidence in the peaks of the two main allergens, *Olea* and grasses, occurred. Moreover, it has been proved that once the symptoms have been triggered off, the amount of pollen has to decrease considerably before symptoms ease [23, 24], and the presence of other particles in the surrounding environment could act as promoters of a symptomatic response. During the days when mowing was being carried out near the building, most of the patients observed a worsening of their symptoms, even presenting an asthmatic crisis in some cases, needing emergency medical treatment. An estimation of the amounts of micro-particles can be obtained from figures 1a and 1b, but it also has to be considered that most of the material had a vegetal origin. As reported by several studies, it is possible that other parts of the plants not related to pollen grains can cause allergic reactions [25-28]. The size of this material is small enough to penetrate the building. The rest of the material identified consists mainly of diesel-exhaust particles from the traffic within and outside the campus. Not much of this type of particle can be observed in the samples inside the building; however, we should take into account material from indoor sources, from where soot might be implicated in irritating effects. Some of the most common components of the photocopying toner include micro-particles of coal and iron as well as copper, chromium, inorganic compounds, cyanide and thermo-plastic particles. Even in not very old machines, a percentage of the components becomes volatile. The effects of inhaling toxic dust from a photocopying machine have been already reported, and are similar to those found in miners who breathe carbon and silica [29].

Among other aggravating circumstances, the meteorological conditions have to be considered. Besides the direct effects that temperature has on release and transportation of pollen throughout the atmosphere and proliferation of fungal colonies, there are other factors more detrimental to health. Excessive heat can cause heat stress, exacerbation of illness and even mortality [30, 31]. On 6 days during the period studied, the temperature reached a maximum above 30ºC, and on one day, May 16th a maximum above 35ºC. This implied that the "thermal environmental conditions at work recommended as acceptable", given as 23-26ºC [32] were widely surpassed. Addition ally to the fact that a high room temperature is related to the occurrence of collective violence [33, 34], individuals suffering from allergy have been identified as one of the groups most sensitive to heat [35]. The high degree of sensitivity may also exacerbate symptoms or increase a predisposition to suffer from them. Another influencing factor was the precipitation (2.6mm) which fell on May 22nd early in the morning between 7 and 8 a.m. Five of the 8 patients participating suffered from a worsening of symptoms in the following hours, two of them (1 and 4) with acute crises and severe breathing difficulties, and the rest with more symptoms than on previous days. An association between epidemics of asthma and rainfall and thunderstorm episodes has been already documented [36, 37]. Similarly to an occurrence in the London area, the pollen records in the hours before the storm were very high. On May 21st, a peak of more than 700 grass pollen grains per cubic metre of air was measured in the samplers placed at 1.5m and 15m a.g.l. With this extremely high amount of pollen in the air and the particular prevalent weather conditions, broken grains and allergens from varying-sized paucimicronized aerosols should also be borne in mind [38-40, 26].

In view of the above mentioned circumstances, it can be concluded that the worsening of symptoms experienced by the workers of the lab suffering from allergy was caused by the coincidence of several occasional factors. However, it has to be taken into consideration that permanent exposure to hazardous material (aerobiological samplers), although minimal, may be detrimental to health. On the other hand, the aerobiological knowledge of these workers is, at the same time, a tool that enables them to adopt preventive measures. Knowing with accuracy the atmospheric biological content at any moment, they can adapt their treatment, avoiding indiscriminate taking of medication. Lastly, and additionally, their own experience may be used as a resource to improve the quality of the reports generated, because nobody can better understand what an allergy patient goes through than another allergy sufferer.

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Dr. Paloma Cariñanos

Plant Biology Department. University of Córdoba
Campus Universitario de Rabanales
Edificio Celestino Mutis. Crta. Madrid, km 396. E-14071
Córdoba, Spain
Phone: +34 957 218719
Fax: +34 957 218598
E-mail: bvlbotan@uco.es

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